Navy Personnel Research, Studies, and Technology Department
Navy Personnel Command (NPRST/PERS-1)
Millington, TN 38055-1000 NPRST-TN-04-2 March 2004

Retention Model Verification

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20040413 075

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Millington, TN 38055-1100
www.nprst.navy.mil

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
31-03-2004		

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Retention Model Verification	
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Rodney S. Myers, Geetha Mandava	
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
Navy Personnel Research, Studies, & Technology (NPRST/PERS-1) 5720 Integrity Dr. Millington, TN 38055-1000	NPRST-TN-04-2

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
Center for Career Development (CCD) Navy Personnel Command 5720 Integrity Dr. Millington, TN 38055	CCD
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

A - Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

As part of their ongoing function of tracking, reporting and analyzing retention measures, the Center for Career Development (CCD) has developed a simple model to evaluate the effects on enlisted end-strength as reenlistment and attrition rates change. To verify the model's accuracy, CCD requested the Navy Personnel Research, Studies, and Technology (NPRST) organization conduct a verification of the model relative to its intended purpose. NPRST's verification focused on determining whether the conceptual model (business assumptions) have been correctly translated into the computer model.

15. SUBJECT TERMS

Retention, Career Development, Forecasting, Reenlistment, Attrition, Forecast Accuracy, and Forecast Error

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Kay Bailey
					19b. TELEPHONE NUMBER *(Include area code)*
UNCLAS	UNCLAS	UNCLAS	UNCLAS	12	901-874-2115 (DSN 882)

Foreword

This model verification was conducted during the fourth quarter of fiscal year 2003. This work was requested by the Center for Career Development as part of their ongoing function of tracking, reporting and analyzing retention measures.

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Director

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Study Report

Purpose

The purpose of this study report is to discuss NPRST's findings and conclusions during the verification of the Center for Career Development (CCD) Retention Model.

Background

PERS-6 provides a monthly executive summary of enlisted reenlistment and attrition rates by length of service zone, e.g., Zones A through E to Senior Navy leadership (CNO, CNP, etc.). To understand these rates a simple model was developed, using Microsoft Excel, to evaluate the effects on enlisted end-strength as reenlistment and attrition rates change. Concentrating on these rates, the model has a total of 13 inputs: actual begin strength at the beginning of a 12-month period, number of planned accessions minus TAR Enlistment Program (TEP) during a 12-month period, reenlistment rates generated from the Retention Monitoring System (RMS) by zone during the 12-month period, attrition rates by zone during the 12-month period, and a predetermined value for USN/USNR other accessions. The model has only ONE output, enlisted end-strength at the end of a 12-month period.

Verification

Regardless of the problem and the modeling paradigm that is used to model a system, a modeling team amplifies the success of a simulation study when the model has been verified, validated, and accredited for use to analyze a specific problem[1]. This process is called Verification, Validation, and Accreditation, or VV&A, and is usually the responsibility of the model's sponsor. The model's sponsor is the agency that provides the funding. The sponsor is closely associated with the ultimate end-user and may even be the end-user. In this case, CCD is acting as the sponsor and the user, however, results implicit and explicit from this model are likely to be used by a wider audience, i.e., within Navy Personnel Command.

VV&A terms are defined; Verification is concerned with determining whether the conceptual model (model assumptions) have been correctly translated into a computer "program," i.e., debugging the computer program. Although verification is a simple concept, debugging a model can be a difficult and arduous task due to the potentially large number of variables and logic paths. Validation is the process of determining whether a model, as opposed to the computer program, is a reasonable representation of the system being studied, for the particular objective(s) of the study. Lastly, a model, and its results, will be accredited if it has "creditability." A model is credible if the user accepts it as "accurate." A credible model is not necessarily valid, and vise versa. Also, a model can be credible and NOT actually used as an aid in making decisions. Although

[1] Myers, R. & McDevitt, M. (in press). *Analytical Modeling Methodologies for Personnel Policy Development and Decision Support.*

our analysis of the model will help to support the model's accreditation, our analysis is focused on verification only.

Mathematical Model

In general, the Retention Model is a combination of a mathematical model, and a forecasting technique. For this particular projection model, the basic mathematical model is:

Projected End-strength = Begin Inventory + Accessions – Losses + Error

This equation describes the relationship between error, losses, accessions, begin inventory, and projected end-strength. This mathematical relation describes the operation of determining projected end-strength - or the mathematical model of projected end-strength. Frequently, mathematical models describe functional relationships.

Projected End-strength = f(Begin Inventory, Accessions, Losses)

This could also be described as projected end-strength being dependent on begin inventory, accessions, and losses, where projected end-strength is the dependent variable, and begin inventory, accessions, and losses are independent variables. Throughout this report predicted, projected, and forecasted will be used interchangeably.

Forecasting Technique and Error Verification

The retention model generates a forecast of enlisted end-strength for the end of a 12-month period. The forecasting technique used is known as extrapolation. Extrapolation is a quantitative forecasting tool that uses ONLY the previous value of the variable being forecast in the analysis. Extrapolation provides a convenient way to generate quick and easy forecasts for the SHORT time horizon; i.e., days, weeks, months, quarter, and at most a year ahead. The benefit of this technique is that it generally requires little to no historical data prior to the implementation of the technique, and it requires only simple arithmetic (as discussed previously) to generate a forecast[2].

There are three basics assumptions in using extrapolation: forecasts are NOT affected by environment, forecasts will NOT immediately recognize turning points, and trends can be identified and separated. The only variables used in the extrapolation are the variables being forecast, and the variables used in the equation. Therefore, all other influences that may impact the variable are excluded from the analysis and the forecast. The forecast is only based on previous actual values of the variables. Therefore, the forecast will not change direction until after the actual data has shown that change. The technique generally expects stationary data (no trend) and if a trend is present in the data, will usually treat the trend as a straight line (linear) trend.

The evaluation of any forecasting technique relies primarily on the comparison of the forecasts with the corresponding actual values. Some evaluation methods are[3]:

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[2] Armstrong, J. (2001). *Principles of Forecasting, A Handbook for Researchers and Practitioners.* Norwall, MA. Kluwer Academic Publishers.

[3] Jensen, A. (n.d.). *Naïve Forecasting Techniques.* Retrieved August 7, 2003. htty://www.csus.edu/indiv/j/jensena/mgmt105/naïve_01.ppt.

- Mean Error
- Mean Absolute Error
- Mean Squared Error
- Absolute Error
- Percentage Error

The Mean Error can be very misleading. A Mean Error value of zero can indicate that the method forecast the actual values perfectly (unlikely) or that the positive and negative errors cancelled each other. Because of this cancellation effect, it tends to understate the error. The Mean Absolute Error is a way of dealing with the understatement of Mean Error. By using the absolute values of the error, the mean gives a better indication of the model's fit. The Mean Squared Error eliminates the positive/negative problem by squaring the errors. The result tends to place more emphasis on the larger errors, and, therefore, gives a more conservative measure than the Mean Absolute Error. The previous three measures are "series specific;" i.e., they only allow evaluation of the series that generated the errors. The Absolute Error is the absolute value difference between the forecast value, and its actual value, and sometimes is taken without absolute value. When taken without the absolute value, the result will maintain its signed value, e.g., exact error. The Percentage Error is 100 percent times the relative error, whereas relative error is the forecast value minus the actual value divided by the actual value. The Percentage Error uses the exact error relative to the actual value, and is designed to allow comparison of the results with different models.

Since we are concerned with the accuracy of the end-strength projection, based on 10 data points, we will use Absolute Error and Percentage Error to measure the prediction accuracy of the model.

$$\textit{Absolute Error} = |\ \textit{Predicted Value} - \textit{Actual Value}\ |$$

$$\textit{Percentage Error} = \frac{\textit{Predicted Value} - \textit{Actual Value}}{\textit{Actual Value}} * 100$$

Equations

Theoretical Equation:

Projected End-strength = Begin Inventory + Accessions – Losses + Error,

Whereas,

Begin Inventory = onboard enlisted inventory at the end of the previous FY (or at the end of a 12-month period)

Accessions = planned gains

Losses = Attrition losses + EAOS losses

*Attrition losses = (Begin Inventory + Accessions) * Attrition Rate*

*EAOS losses = (1 – Reenlistment Rate) * Eligibles*

Eligible ≤ 90 days prior to EAOS and Non-Eligible > 90 days prior to EAOS

Error = randomly distributed error term, which represents the difference between overestimation and/or underestimation of independent variables

Figure 1. Describes the process by which Non-EAOS Inventory and Reenlistments are derived.

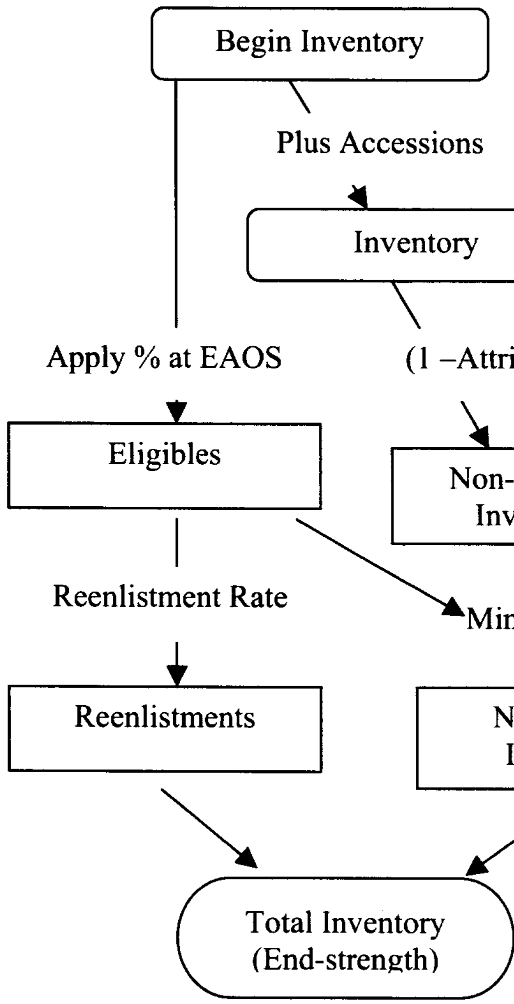

Figure 1. Equation Diagram.

Eligibles are computed by applying the percentage at EAOS (historical average) to the current inventory. The historical average is determined from RMS and used as input.

The retention model uses the following equations:

Projected Inventory (end-strength) = Non EAOS Inventory + Reenlistments,

Whereas,

Inventory = Begin Inventory + Accessions

Accessions include Prior service (NAVET/OSVET, Reserve Recall), and Non-prior service (USN and USNR), taken from the N13 accession implementation plan. For the purpose of attrition calculation, accession attrition is calculated using the same attrition rates as non-eligible. Also, the mathematical model includes a predetermined number (3737) to account for USN/USNR Other accessions. This number is an approximation of USN/USNR Other accessions, based on fiscal year (FY) 2003. In reality, it is subject to change for upcoming years.

An adjustment value is necessary because it is assumed that USN/USNR Other accessions attrite at a greater rate than any other population in the model. To account for this unknown, the most recent historical data for a minimum of six months is reviewed to determine the numerical adjustment required to reduce the numerical error of the model for the six months being evaluated. This evaluation is performed on a by-month basis. The model developer chose six months as the data window, because the analysis revealed a consistent delta for a 6-month period between actual end-strength and the model results. Beyond six months, the delta began to decrease. This should be analyzed separately for each update to the model to determine the best data window for this adjustment. However, the model developer warns against decreasing the window below six months.

To calculate the adjustment value, use the results from previous six months to determine the actual errors (difference between forecasted and actual) for each individual month. For example, if the target forecast month is October of a given year, calculate the actual error for a minimum of six previous months, e.g., September, August, July, June, May, and April. Next, determine the minimum (Min) and maximum (Max) actual error for the 6-month period. Then choose an adjustment value that is the midpoint between the six-month maximum and minimum. The following is used to calculate the adjustment value for the 6-month period:

Max – Adjustment = Min + Adjustment

Max = Min+ 2Adjustment

Adjustment = (Max - Min)/2

Inventory is adjusted for attrition via the following equation:

*Non-Attrition Inventory = (1 - Attrition Rate) * Inventory*

Inventory is further revised to account for reenlistment eligibles via the following equation:

Non-EAOS Inventory = Non-Attrition Inventory – Eligible (eligible to make a reenlistment decision)

*Reenlistments = Reenlistment Rate * Eligible*

Additionally, the model uses an adjustment feature for attrition rates to provide fidelity by zone. In other words, the model provided good answers for the forecast of total end-strength, at the end of the 12 month forecast period. However when looking at changes in attrition rate by zone, improvements in length of service (LOS) profile were necessary to reflect actual results in current attrition. For example in FY02, we knew the average inventory in Zone A was 158,800 (for the 12 month period). Therefore this adjustment feature is used to achieve the 158,800 Zone A LOS population. Calculate the attrition adjustment factor for each particular fiscal year by using the following equation: (projected inventory by Zone [model] / average actual inventory by zone [RMS]). This adjustment feature is imbedded in the model.

A similar adjustment is used for reenlistment rate. The adjustment for reenlistment rate is used to achieve the current number of eligibles. First, use the model to calculate the total inventory in each particular zone after attrition occurs. Then the adjustment is used to create the correct number of eligibles for a recent fiscal year. For example, in FY02, we know the number of eligibles in FY02 was 24,500 for Zone A. Therefore the adjustment for reenlistments considers the fraction of the population after attrition to reflect 24,500 eligible for reenlistment in Zone A. Calculate the reenlistment adjustment rate for each fiscal year by using the following equation: (actual eligible population by zone [RMS] / projected population after attrition by zone [model]).

RMS data is generated as follows:

$$\textit{Reenlistment Rate} = \frac{\textit{Reenlistments + Long Term Extensions}}{\textit{Reenlistments + Long Term Extensions + EAOS Losses}}$$

$$\textit{Attrition Rate} = \frac{\textit{Non-EAOS Losses}}{\textit{Non EAOS Inventory}}$$

Both reenlistment and attrition rates are cumulative averages of the actual reenlistment and attrition behavior over the current 12 months taken from RMS. Non-EAOS are the personnel not eligible for reenlistment.

Forecast Verification Results

The actual enlisted end-strength numbers for the previous 10 years were provided and verified by N132 (Director, Enlisted Strength Planning).

Table 1 contains the end-strength forecast verification results for the past ten years (FY93–FY02). The rows represent fiscal years; the columns represent actual end-strength, forecast end-strength using the retention model, and calculated Absolute Error and Percentage Error.

Table 1. Analysis of Forecast Results

Fiscal Year	Actual End-strength	Forecast End-strength	Absolute Error	Percentage Error
1993	439,433	446,375	6942	1.580
1994	402,626	408,000	5374	1.335
1995	371,670	374.620	2950	.794
1996	355,048	350,595	4453	-1.254
1997	335,267	335,443	176	.053
1998	323,120	318,015	5105	-1.580
1999	315,178	312,167	3011	-0.955
2000	315,471	313,586	1885	-0.597
2001	319,601	318,208	1393	-0.436
2002	324,351	321,836	2515	-0.775

We were not given a target Percentage Error or Absolute Error. However, in past experience, we have been using two percent error as a target for forecast that are within six months. During past literature reviews, we were unable to determine an industry standard for percentage error. It appears standards are set based on the objectives of the particular study.

The forecast end-strength was calculated as follows: the begin inventory was taken from previous year's actual end-strength, the planned accessions were taken from the N13 accession implementation plan for the year being forecast, the percentage at EAOS and the cumulative 12 months' reenlistment and attrition rates were taken from RMS. The predetermined additional USN/USNR other accessions (3737) were assumed for each fiscal year, without exception. Further, the end-strength calculations follow the equation diagram (Figure 1) outlined in this study report, including adjustments.

The range for percentage error was -1.580 to 1.580. The largest percentage error occurred in 1993 and 1998, relative to each individual year. For 1993, the model over projected the end-strength, while in 1998, the model under projected the end-strength. These distinctions may be relevant depending on the fiscal year being analyzed in other studies or planning exercises. The smallest error occurred in 1997, where the model over projected the end-strength. Fiscal years 1994 and 1996 were closer to the larger percentage error with values of 1.335 and -1.254 respectively. Typically, we would expect to have less of a percentage error given the known variables, however, in this 10 year period, the model developer assumed several constant values, including number of TAR Enlisted Program (TEPs), the adjustment value, and the number of USN/USNR Other accessions for each year.

Figure 2 shows the actual end-strength vs. forecasted end-strength for 1993 thru 2002.

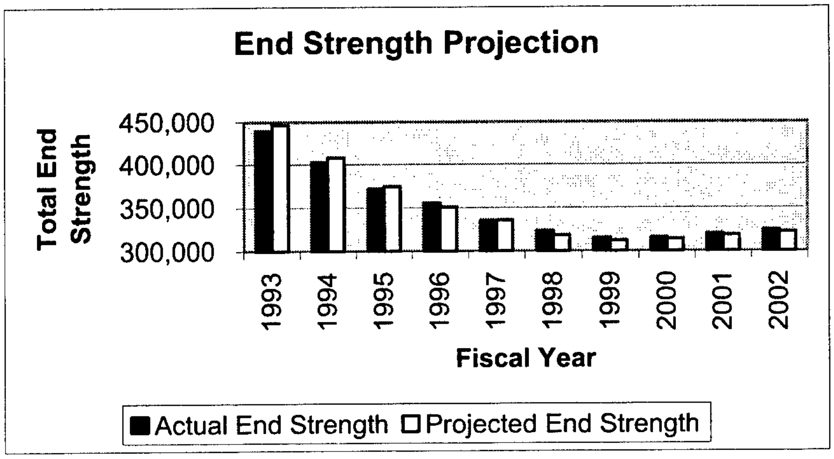

Figure 2. End-strength Projection.

Figure 3 shows the absolute error, which was calculated based on the absolute value difference between the actual end-strength and the forecasted end-strength (see "error verification").

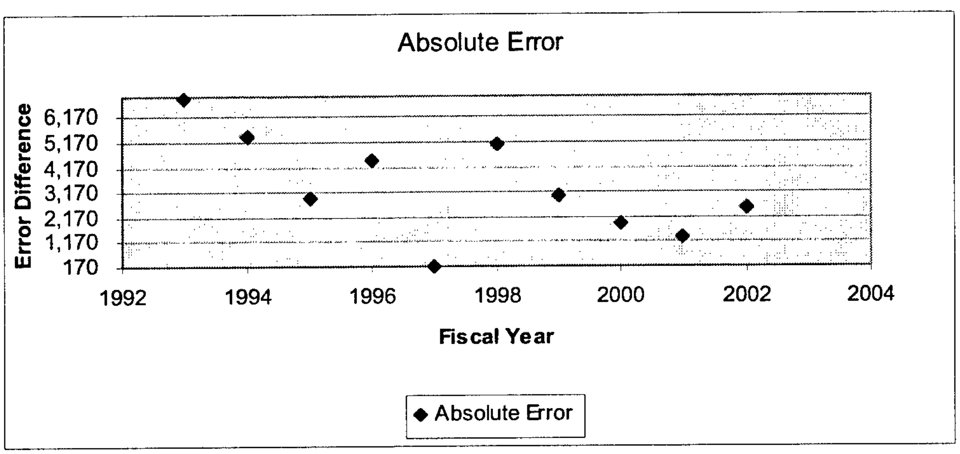

Figure 3. Absolute Error.

Figure 4 shows the percentage error, which was calculated based on the percentage difference between the actual end-strength and the forecasted end-strength (see "error verification").

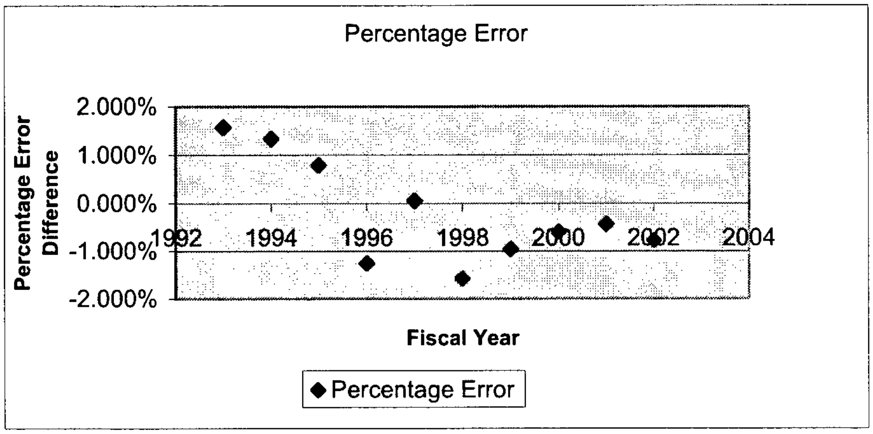

Figure 4. Percentage Error

Conclusions

The Retention Model contains sufficient mathematical equations and business rules to perform alternative analysis of the impact on enlisted end-strength—as accessions change, and more importantly as reenlistment rates and attrition rates change. Additionally, the projected end-strength derived from the mathematical model, including adjustments, could be used as an estimate of enlisted end-strength for a 12-month period. The forecasting processes and equations are logical and traceable.

This model does NOT capture the level of detail that is modeled in the existing strength planning and community management models and should NOT be considered as a replacement for either. However, this model does represent a good supplement to existing planning methods and tools. Properly employed, this tool can provide a reasonable forecast of Navy end-strength that results from changing accessions, reenlistment and/or attrition goals.

Appendix A

Glossary

Accessions	Gain to Strength
Attrition	Non-EAOS loss to strength
CDR	Commander
CNO	Chief of Naval Operations
CNP	Chief of Naval Personnel
CNRC	Commander, Navy Recruiting Command
EAOS	Expiration of Active Obligated Service
Eligible	Eligible to make a re-enlistment decision
End-Strength	Inventory (strength) at the end of a period of time
LCDR	Lieutenant Commander
Long Term Extension	>24 months extension of contract
LOS Zones	A = <6 years of service B = 6–10 years of service C = 10–14 years of service D = 14–20 years of service E = >20 years of service
NAVET	Navy Veteran
OSVET	Other Service Veteran
Reenlistment	Renewal of enlistment contract
Reserve Recall	Reserve member called back to active duty
TAR	Training and Administration of Reserves
TEP	TAR Enlistment Program
USN	United States Navy
USNR	United States Navy Reserve

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